23rd Gas Conference, Amsterdam 2006

LIFE CYCLE ASSESSMENT OF A NATURAL GAS PLANT: CASE STUDY-SARKHOON GAS TREATING PLANT IN IRAN

Main Author

Gh. Bahmannia

IRAN

1. ABSTRACT

Life cycle assessment (LCA) of Sarkhoon gas treatment plant in Bandar Abbas-Iran has performed to examine the net emissions of greenhouse gases, as well as other major environmental consequences. LCA is a systematic analytical method that helps identify and evaluate the environmental impacts of specific process or competing processes. In order to quantify the emissions, resource consumption, and energy use (i.e., environmental stressors), material and energy balances are performed in cradle-to-grave manner on the operations required to transfer raw materials in to useful products. The purpose of this paper is to focus on LCA by establishing the balance of energy and GHG emissions throughout the life cycle of the all main sources in plant.

The used methodology is governed by ISO 14040-14043 which describes the various steps of LCA. The key elements of this study are:

1- System description and major assumptions
2- System boundaries
3- Natural gas compositions
4- Natural gas losses
5- Emissions identification and monitoring
6- Results
7- Impact assessment
8- Improvement opportunities
10- Summaries

TABLE OF CONTENTS

1. Abstract

2. Life Cycle Assessment of Sarkhoon Gas Treating Plant

    2.1 Introduction
    2.2 Sarkhoon Gas Treatment Plant Description and Assumptions
    2.3 System Boundaries and major assumptions
    2.4 Construction Material Requirements
    2.5 Natural Gas Composition and Losses
    2.6 Emissions Identification and monitoring
    2.7 Results
        2.7.1 Air Emissions
        2.7.2 Greenhouse Gases and Global Warming Potentials
        2.7.3 Energy Consumption and System Energy Balance
        2.7.4 Resource Consumption
        2.7.5 Water Emissions
        2.7.6 Solid Waste

    2.8 Sensitivity Analysis
    2.9 Impact Assessment
    2.10 Improvement Opportunities

3. References
4. List of Tables
5. List of figures

2. LIFE CYCLE ASSESSMENT OF SARKHOON GAS TREATMENT PLANT

2.1 Introduction

Natural gas still maintains the fastest consumption growth rate among the world's primary energy sources and has the highest consumption growth rate among the developing countries. Based upon "International Energy Prospect" scenario, the global natural gas consumption during years 2001-2025 will experience an average growth rate of 2.9-3.2 % per year which is comparable to annual growth rate of 1.8% for oil and 1.5% for coal. Currently, natural gas accounts for nearly half of Iran's total energy consumption, and the government plans billions of dollars worth of further investment in coming years to increase this share.

The country's gas treating capacity during years 1997-2005 indicates a substantial of 189.6 million cubic meters per day. The treating and dehydration capacity during this period with period with average annual growth of 14.3 percent, increased from 128.5 million cubic meters per day in year 1996 to 383 million cubic meters per day in 2005.

Increasing natural gas share in the demand basket of Iran will in effect decrease annual growth rate of carbon dioxide dissipation from 4.2% in year 1994 to 2.4 in year 2021.Natural gas disperse the least amount of green house gases especially carbon dioxide compared to other fossil fuels for a fixed amount of energy production (Kyoto protocol discussion concerning climate changes).Increasing of country's gas treating capacities during years 2005-2025 should be considered from environmental point of view.

The primary goal of LCA in Sarkhoon gas treating plant as a case study is to quantify and analyze the total environmental aspects of producing dry pipeline gas (plus side-products LPG and condensate) via traditional treatment processes as a typical gas plant in Iran. The size of the Sarkhoon gas treating plant is 14.4 million normal cubic meters per day which is typical of small scale size that would be found at today's country gas plants.

2.2 Sarkhoon Gas Treatment Plant Description and Assumptions

This plant is located 25 kilometers to the north-east of Bandar Abbas. Whole project have been completed with daily production capacity of 14.4 million cubic meters of natural gas, 12000 barrels of stabilized condensate and 90 tons of LPG. The natural gas required is provided by he 13 existing sour and sweet wells which are then transmitted to the plant. The processing units of the plant , which have been designed and installed by acquiring the latest technology , sweetening , de-hydration , glycol recovery , refrigerating with propane , NGL stabilizing and LPG producing units . In addition the power generation of the plant enjoys three gas-turbines with a total capacity of 7.2 M.W of electrical energy. The produced natural gas is transmitted to Bandar Abbas to supply the fuel requirements of its power plants and other industries and domestic households of two provinces. On the other hand stabilized liquid hydrocarbons, separated from natural gas in this treatment plant are transported to Bandar Abbas oil refinery which makes up part of its feedstock. Produced LPG's transferred to storage tanks and then distributed to some domestic households.

Figure 1 is a block flow diagram of the natural gas plant studied in this analysis. The feedstock is two phase well head gas stream that transferred to plant by gathering lines. Main processes of plant are: initial separation, sweetening, dehydration of gas and condensate stabilizing. The material and energy balance data for plant were taken from HYSYS simulation software and verified by actual data logging and monitoring of on site. For comparison, a sensitivity analysis was performed to examine the difference in the overall emissions.

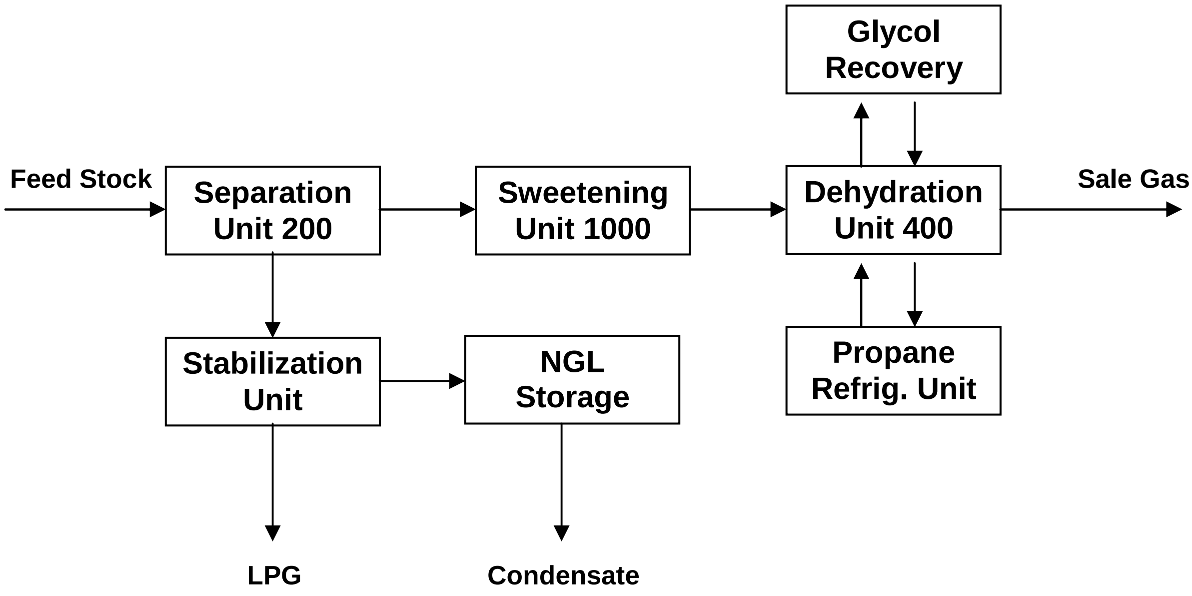

FIG 1: Sarkhoon block flow diagram of the natural gas plant

Parameter	SOUR GAS PHASE 1	SOUR GAS PHASE 2	SWEET GAS PHASE 1	SWEET GAS PHASE 2	OUT LET WATER	TOTAL INLET	SALE GAS	LPG	NGL	FLARE 1000	FUEL 830	FUEL 400	TOTAL FUEL
C1(Kgmol/h)	4486.273	3850.937	3046.459	9994.895	0	21378.5635	21181.67	0	0	2.4	11.3	83.0836	96.7836
C2	185.2	159	128.7	429.4	0	902.3	869.2937	0	0	0.1	23.1	9.5771	32.7771
C3	75	64.4	50.7	165.8	0	355.9	321.1649	23.2	0	0	0	5.2531	5.2531
IC4	18.1	15.5	11.9	38	0	83.5	67.9227	12.9	0.1	0	0	1.2422	1.2422
N C4	27.4	23.5	18	57.6	0	126.5	96.3025	25.9	0.4	0	0	1.8631	1.8631
iC5	12.9	11.1	8.4	26.5	0	58.9	34.8599	1.3	21.3	0	0	0.6829	0.6829
NC5	10.3	8.9	6.8	21.9	0	47.9	24.9943	0.1	21.8	0	0	0.5115	0.5115
N-C6	12.9	11.1	8.8	28.8	0	61.6	15.8939	0	44.9	0	0	0.3298	0.3298
N-C7	12.9	11.1	8.6	27.6	0	60.2	0	0	0	0	0	0	0
NC8	10.3	8.9	8.4	31.1	0	58.7	0	0	0	0	0	0	0
NC9	7.8	6.7	5.3	17.3	0	37.1	0	0	0	0	0	0	0
NC10	6.7	5.8	4.2	12.7	0	29.4	0	0	0	0	0	0	0
NC11	6.2	5.3	3.6	10.4	0	25.5	0	0	0	0	0	0	0
NC12	5.7	4.9	3.1	8.1	0	21.8	0	0	0	0	0	0	0
NC13	2.1	1.8	1.4	4.6	0	9.9	0	0	0	0	0	0	0
NC14	1.6	1.3	1	3.1	0	7	0	0	0	0	0	0	0
NC15	1.5518	1.332	0.6479	1.1512	0	4.6829	0	0	0	0	0	0	0
NC16	1.0345	0.888	0.4589	0.921	0	3.3024	0	0	0	0	0	0	0
NC17	0.5173	0.444	0.2903	0.8059	0	2.0575	0	0	0	0	0	0	0
NC18	0.5173	0.4444	0.27	0.6907	0	1.9224	0	0	0	0	0	0	0
NC19	0.5173	0.444	0.2497	0.5756	0	1.7866	0	0	0	0	0	0	0
NC20	1.5518	1.332	0.5871	0.8059	0	4.2768	0	0	0	0	0	0.4723	0.4723
N2	240.0124	206.0217	173.0164	591.728	0.0001	1210.7785	1206.085	0	0	84.8	0.1	1.8565	86.7565
CO2	45.5194	39.0732	19.7475	37.9901	0.0008	142.3302	56.7933	0	0	0.7	0	0.001	0.701
H2S	0.2671	0.3905	0.0161	0.0576	0	0.7313	0.0735	0	0	0	0	0	0
DEA	0	0	0	0	0.0001	0	0	0	0	0	0	0	0
DEG	0	0	0	0	0	0	0	0	0	0	0	0	0
H2O	66.5668	50.4878	32.4233	164.3864	79.3923	313.8643	0.534	0	0	7.9	2.3	0.0984	10.2984
Molar flow	123885.5	106187.6	83770.2	276087.7	1877.2	589931	564695.4	1496	8227	2269.9	3577.9	2485.5	8333.3
Mass flow	104679	89740.1	70111.7	229302	1430.31	493832.8	432398	3371	43144	3944	3257	2238	9439
Actual volume flow	1775.1	1490	1130.1	3721.2	1.4	8116.4	8624.4	6.7	63.2	1439.4	263.5	89.4	1792.3
Std gas flow	123885.5	106187.6	83770.21	276087.7	187721	589931.05	564695.4	1.50E+03	8.23E+03	2270	3578	2485.54	8333.54
Temperature	65.87	57.6	49.2	46	47.8	54.6675	50.5	55.91	60.53	53.98	64.84	31.3	50.04
Pressure	72.49	71.49	71.69	70.49	25.99	71.54	65.59	15.69	10	0.7868	14.49	25.98	13.75226667
Molar weight	19.98	19.98	19.79	19.64	18.02	19.84	18.1	53.28	124	41.08	21.52	21.29	27.96333333
Mass density	58.969	60.228	62.041	61.621	990.872	60.7	50.137	504.214	682.443	2.74	12.36	25.018	13.37266667
Vapour fraction	0.979	0.977	0.978	0.973	0		1	0	0	1	1	1	1
power(kw)	-1.17E+05	-1.01E+05	-7.80E+04	-2.57E+05	-6.24E+03	-1.12E+05	-4.87E+05	-8.56E+06	-8.95E+07	2.83E+02	7.53E+02	-2.36E+03	-4.43E+02
heat flow(kj/h)	-4.22E+08	-3.62E+08	-2.81E+08	-9.26E+08	-2.25E+07	-4.03E+08	-1.76E+09	-2.38E+03	-2.49E+04	1.02E+06	2.71E+06	-8.51E+06	-1.59E+06

Table 1: Material and Energy Balance in Natural Gas Plant

Prior to transmitting of natural gas to sweetening unit, feed stock separate to three phases –Gas, condensate, water- in initial separation unit at 70 bar and 50-60 C and then in sweetening unit acid gases(CO_2, H_2S) removed by DEA 30% solution from gas stream in absorber tower. Dehydration and water/hydrocarbon dew point control process is perform by injection of DEG 35% solution and Propane refrigerant in closed cycle. Sale gas in standard quality and dew point transmits to 515 km pipeline for domestic uses. Through stabilization unit after stabilizing condensate in atmospheric pressure, LPG product transfers to storage tanks. In Table 2 some useful plant data are presented.

Design Parameter	**Data**
Plant size	14.4 mmscm/D Gas 12000 bbl/D NGL 90 tones LPG
Average Operating Capacity Factor	95%
Fuel Gas Consumption	100000 Cubic meter/D
Electricity Requirement	2.4 MWatt/D
Natural Gas Plant Energy Efficiency (Total energy produced/Total energy into plant	95%

Table 2: Natural Gas Plant Data

For heating purposes, this gas plant enjoys a closed hot oil system and some heaters and for supply of electricity demand of plant, gas turbines with 40% efficiency are installed. Monitoring of all fuel consumptions, flares, flue gases, energy generations and feed stock, all products and solid or liquid wastes is available through on line DCS system, accurate sensors and data logging systems in plant. In addition flue gas composition and particulate emissions were obtained from the U.S. Environmental Protection Agency's (EPA) data on natural gas combustion furnaces (EPA, 1995). The amount of the pollutant in this paper is given per the quantity of natural gas HHV of 8270 kcal/cubic meters.

2.3 System Boundaries and Major Assumptions

The software package used to track the material and energy flows between the process blocks in the system was HYSYS, TEAM, and plant DCS software. FIG 2 shows the boundaries for system. The solid lines in the figure represent actual material and energy flows; the dotted lines indicate logical connections between process blocks. The stressors associated with natural gas production and distribution, as well as those for electricity generation, are taken from the TEAM and compared with collected through Plant data acquisition system. The steps associated with obtaining the natural gas feedstock are drilling/extraction, gathering pipelines. The emissions associated with each process step in the natural gas production, gathering, treatment, transportation and electricity production are through Ecobalance, Inc. and the fact data book of National Iranian Gas Co. (NIGC). The heaters and furnaces efficiency in plant is assumed 75% and for this study, the plant life was set at 20 years with 2 years of construction. In year one, the gas plant begins to operate; plant construction takes place in the two years to this (years negative two and negative one). In year one the gas plant is assumed to operate only 70% of the time due to start-up activities. In years one through 19, normal plant operation occurs, with 95% capacity factor. During the last quarter of year 20 the gas plant is decommissioned.

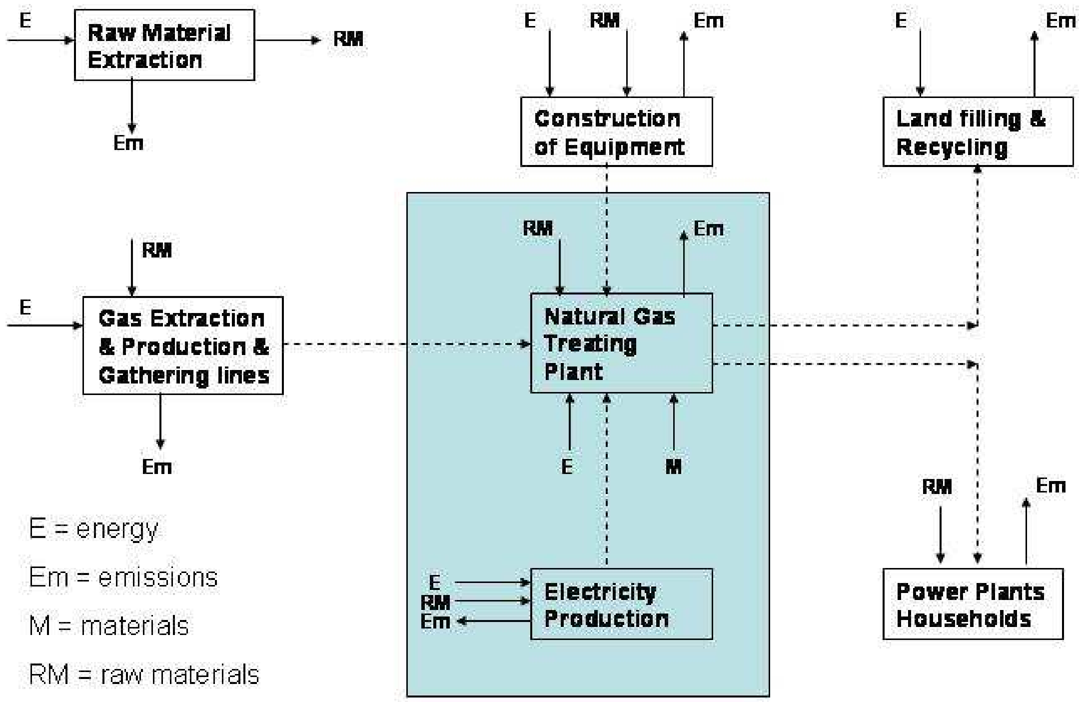

FIG 2: System Boundaries for Natural Gas Treating Plant

2.4 Construction Material Requirement

Method for determining plant construction and decommissioning are based on calculating plant available actual data and some internal state economical statistics. A sensitivity analysis was performed to determine how changing these numbers would affect the results. The gas plant with electricity generation unit used following materials:

Concrete	20450	Mg
Steel	5272	Mg
Aluminum	570	Mg
Iron	740	Mg

The main gathering pipeline for gas feedstock is 50.8 cm in diameters and 20 kilometers length. A sensitivity analysis was performed using different pipe diameters to determine the effect of material requirements on the results. Emission of installing the pipe line is included in the analysis.

2.5 Natural Gas Composition and Losses

Table 3 gives the actual composition of the natural gas feedstock used in this analysis, as well as sale gas. In extracting, processing, transmitting, storing, and distributing natural gas, some is lost to atmosphere. Fugitive emissions are the largest source, accounting for about 38% of the total, and nearly 90% of fugitive emissions are a result of leaking well head and compressor components (Resch, 1995 and Harrison et al, 1997). The second largest source of methane emissions comes from pneumatic control devices, accounting for approximately 20% of the total losses (Resch, 1995). The majority of the pneumatic losses happen during the extraction step.

According to the EPA, transmission and storage account for the largest portion of the total methane emissions at 37% followed by extraction at 27% distribution at 24% and processing contributing the least at 12% (that will determine again in this paper).Many publications are used in this paper such as; EPA/GRI/AGA and Perry handbook.

Component	Feedstock of Plant (mol%)	Sale Gas (mol%)
Methane	85.73	88.15
Ethane	3.54	3.27
i+n Butane	0.87	0.74
i+n Pentane	0.45	0.27
C6	1.36	0.17
Nitrogen	4.59	5.21
Carbon Dioxide	0.87	0.30
Hydrogen Sulfide (ppm)	0.01	0.17
Water	1.15	0.03
Net Heat Value Btu/Cubic Ft	1320	1000
Specific Gravity	0.710	0.6303

Table 3: Natural Gas composition in Feedstock and Sale Gas of Plant

Natural gas feedstock in gas plant are obtained through 13 wells by gathering pipelines that are sweet or sour streams but in this study we assumed that all are sour. There are no any booster compressors or facilities in feedstock line. The base case of this LCA assumed that 1.4% of the natural gas that is produced for gas plant feed is lost to atmosphere due to fugitive emissions. The emissions of gas plant could be calculated accurately.

2.6 Emissions Identification and monitoring

Emission identification and monitoring in Sarkhoon gas refinery has performed by expert HSE group and by accurate analyzers or lab tests in suitable time intervals based on standards.

2.7 Results

The results of this LCA, including air emissions, energy requirements, resource consumption, water emissions, and solid wastes are presented here. The functional unit, also known as the production amount that represents the basis for analysis, was chosen to be the net amount of natural gas produced (sale gas). Most values are given per kg of natural gas, averaged over the life of the system so that the relative contribution of stressors from the various operations could be examined. Because there source consumption, emissions, and energy use are functions of the size of the plant and the technology, care should be taken in scaling results to larger or smaller facilities, or applying them to other natural gas treating plant systems.

All results of this LCA have checked and compared with actual site data which gathered and monitored by HSE site experts. Some formulas for calculation of GHG emissions through combustion processes are developed by them.

2.7.1 Air Emissions

In terms of total air emissions, CO2 is emitted in the greatest quantity, accounting for 99 wt% of the total air emissions. The vast majority of the CO2 (84%) is released at the natural gas plant. Table 4 is a list of the major air emissions as well as breakdown of the percentage of each emissions from the following subsystems: construction and decommissioning, gas wellhead production and transport, electricity generation at site, natural gas treating plant,….After CO2, methane is emitted in the next greatest quantity followed by non-methane hydrocarbons (NMHCs), NOx, Sox, CO, particulates, benzene, and N2O. In natural gas plant the major emissions are belonged to flares, heaters, furnaces, gas turbines (for driving the compressors and electricity generation), reboilers and burn pits. Because the importance of CO2, following formulas helps to calculate the amount of CO2 emissions in different equipments at site:

Gas Turbines CO2 emission (kg/day) = 0.442 multiply equipment fuel gas consumption STD m^3/day
Heaters CO2 emission (kg/day) = 1.35 multiply equipment fuel gas consumption STD m^3/day
Flares CO2 emission (kg/day) = 0.401 multiply equipment fuel gas consumption STD m^3/day

The above mentioned formulas are developed also for other emissions in Sarkhoon natural gas plant and all have checked through monitoring of actual running data.

Air Emission	System Total g/kg of NG	% of total	% of total excluding CO2	% of total gas construction & decomm.	% of total gas production & transport	% of total from electric	% of total from NG plant operation
Benzene	1.4	<0.0%	1.3%	0.0%	110.9%	0.0%	0.0%
CO2	10620.6	99%	-	0.4%	14.8%	2.5%	83.7%
CO	5.7	0.1%	5.3	2.0	106.3	0.7	1.4
CH4	59.8	0.6%	55.7	<0.0	110.8	<0.0	0.0
NOx as No2	12.3	0.1%	11.0	1.8	90.3	9.5	7.3
NO2	0.04	<0.0%	<0.0%	7.3	37.6	58.7	0.0
NMHCs	16.8	0.2%	15.6	1.7	89.8	14.5	0.0
Particulates	2.0	<0.0%	1.8	64.5	25.2	11.6	1.1
Sox as SO2	9.5	0.1%	8.8	13.5	68.3	24.9	0.0

Table 4: Average Air Emission

2.7.2 GHG and Global Warming Potential

Although CO_2 is the most important greenhouse and is the largest emission from this system, quantifying the total amount of greenhouse gases produced is the key to examining the GWP of the system. The GWP of the system is a combination of CO_2, CH_4 and N_2O emissions. The capacity of CH_4 and N_2O to contribute to the warming of the atmosphere is 21 and 310 times higher then CO_2 , respectively , for a 100 year time frame according to the Intergovernmental Panel on Climate Change (IPCC) (Houghton , et al , 1996) . Thus, the GWP of a system can be normalized to CO_2 – equivalence to describe its overall contribution to global climate change. The GWP, as well as the net amount of greenhouse gases are shown in Table 5. It is evident from this table that CO_2 is the main contributor, accounting for 89.3% of the GWP for this specific system. However, it is important to note that the natural gas lost to the atmosphere during production and gathering causes CH_4 to affect the systems GWP. Although the amount of CH_4 emissions is considerably less than the CO_2 emissions on a weight basis (10,621 g of CO_2/kg of H_2 versus 60 g of CH_4/kg of H_2) , because the GWP of CH_4 is 21 times that of CO_2 , CH_4 accounts for 10.6% of the total GWP .

	Emission amount (g/kg of H_2)	Percent of greenhouse gases in this table (%)	GWP relative to CO_2(100 year IPCC values)	GWP value (g CO_2 – equivalent/kg of H_2)	Percent contribution to GWP (%)
CO_2	10,621	99.4	1	10,621	89.3
CH_4	60	0.6	21	1,256	10.6
N_2O	0.04	0.0003	310	11	0.1
GWP	N/A	N/A	N/A	11,888	N/A

Table 5: Greenhouse Gases Emissions and Global Warming Potential

2.7.3 Energy Consumption and System Energy Balance

Energy consumption is an important part of LCA. The energy consumed within the system boundaries results in resource consumption, airman water emissions, and solid wastes. Based on Table 1, the table 6 shows the energy balance for the system and because of its magnitude, the natural gas energy is listed separately. Most of the energy consumed, about 87%, is that contained in the natural gas fed to the gas turbines. Following formulas contains four additional terms for evaluating the energy balance of the system and calculated data are shown below:

Life cycle efficiency % = (Eh2- Eu-Ef) / Ef = - 39.6%
External energy efficiency % = (Eh2-Eu) / Ef = 60.4 %
Net Energy Ratio = Eh2 / Eff = 0.66
External Energy ratio = Eh2 / (Eff – Ef) = 5.1
Where:
Eh2 = energy in the natural gas
Eu = energy consumed by all upstream processes required to operate the gas plant
Ef = energy contained in the natural gas fed to the gas plant
Eff = fossil fuel energy consumed within the system (e)

	System total energy consumption (MJ/kg gas)	%of total in this table	%of total from construction & decommissioning	%of total from natural gas production & gathering	%of total from electricity generation
Energy in the natural gas to gas plant	159.6	87.1%	N/A	1000.0%	N/A
Non-feedstock energy consumed by system	23.6	12.9%	2.4%	169.8%	17.0%
Total energy consumed by system	138.2	N/A	N/A	N/A	N/A

Table 6: Average Energy Requirements (LHV basis)

The energy in the natural gas is greater than the energy content of the gas produced. Therefore; the life cycle efficiency is negative. This reflects the fact because natural gas is non-renewable resource; more energy is consumed by the system than is produced. In calculating the external energy efficiency, the energy content of the natural gas is not included, making the result of this measure positive. The difference between the gas plant efficiency and the external energy efficiency quantifies how much energy is used in upstream processes. The results also that for every MJ of fossil fuel consumed by the system, 0.66 MJ of dry gas are produced (LHV basis). Although the life cycle efficiency and net energy ratio are more correct measures of net energy balance of the system, the external measures are useful because they expose the rate of energy consumption by the upstream process steps. Disregarding the energy in the natural gas feedstock the majority of the total energy consumption comes from natural gas production and gathering (see Table 6), which can be further broken up into sub-processes: natural gas extraction, processing transmission, storage, and gathering. Analyzing each of these steps, it was found that the large amount of energy consumed in natural gas production is specifically from the natural gas extraction and transport steps. Conversely, the energy credit from the avoided operations is also a result of natural gas production and distribution. Note that in general higher efficiencies and energy ratios are desired for any process, not only in terns of economics, but in terms of reduced, resources, emissions, wastes, and energy consumption.

2.7.4 Resource Consumption

Fossil fuels, metals, and minerals are used in converting natural gas to sale gas. Excluding water, the major resource consumption requirements for the system are: as expected, natural gas at the highest rate, accounting for 94.5% of the total resources on a weight basis, followed by, iron (ore plus scrap) at 4.6%, limestone at 0.4%, and oil at 0.4%. The iron and limestone is used in the construction of the power plant and pipeline. The majority of the oil consumption (60.9%) comes from natural gas production and gathering while most of the gas is consumed to produce the electricity and refrigeration process which needed by the gas plant. Following is a breakdown of the water consumption for system and the majority of the water is consumed at the gas plant:

Total Water consumed: 19.8 Lt/Kg gas
Percent of total Water consumed from construction & decommissioning: 3.6 %
Percent of total Water consumed from gas production and transport: 1.3%
Percent of total Water consumed from electricity generation: < 0.0 %
Percent of total Water consumed from gas plant operation: 95.2 %

2.7.5 Water Emissions

Similar to the findings of previously performed LCAs, the total amount of water pollutants was found to be small compared to other emissions, Therefore, a list of the individual components and their quantities is not reported in this document . The total amount of water pollutants for this study equals 0.19 g/kg of gas with the primary pollutant being oils (60%) followed by dissolved matter (29%). It is interesting to note that the water pollutants come primarily from the material manufacturing steps required for pipeline and plant construction.

2.7.6 Solid Waste

The waste produced from the system is miscellaneous non-hazardous waste; totaling 201.6 g/kg of gas produced .Following data contains a breakdown of the percentage of waste from each of the subsystems:

Total Solid Waste: 201.6 Lt/Kg gas
Percent of total Solid Waste from construction & decommissioning: 3.8 %
Percent of total Solid Waste from gas production and transport: 72.3%
Percent of total Solid Waste from electricity generation: 31.0 %
Percent of total Solid Waste from gas plant operation: 7.1 %

The majority (72.3%) comes from natural gas production and gathering. Breaking this down further, pipeline transport is responsible for 50% of the total system waste and natural gas extraction is the second largest waste source, accounting for 22% of the total. Although the majority of the pipeline compressors are driven by reciprocating engines and turbines which are fueled by the natural gas, there some electrical machines and electrical requirements at the compressor stations. The waste due to pipeline transport is a result of this electricity requirement. The remaining system waste comes the grid electricity (31.0%) required to operate the gas plant and from construction and decommissioning (3.8%). Since there are two process steps using a considerable amount of electricity (natural gas pipeline transport and the gas production plant), almost 80% of the system waste is a result of power generation. Because all of the electricity in the plant is generated from gas-fired power plants, the majority of the waste will be in the from flue gas clean-up waste. There is also a small credit for the waste avoided during natural gas production, and combustion (-7.1%). Although this study did not account for any solid wastes from the gas plant itself, it should be noted that the only waste stream from the plant will be a little amount of FeS or minerals in filters.

2.8 Sensitivity Analysis

A sensitivity analysis was conducted to examine the effects of the base case assumptions for several parameters. These parameters and their changes are shown in Table 7. Each parameter was changed independently of all others so that the magnitude of its effect on the base case could be assessed. Therefore, no single sensitivity case represents the best or worst situation under which these systems might operate.

Variable	Sensitivity analysis cases	
Amount of materials required for plant construction	Decrease by 50%	Increase by 50%
Amount of materials required for pipeline construction	Decrease by 20%	Increase by 20%
Natural gas losses(% of gross production)	0.5%	4%
Operating capacity factor	0.80	0.95
Materials recycled versus materials land filled	50/50	
Natural gas boiler efficiency	64%	
Gas plant energy efficiency (HHV basis)	80%	

Table 7: Variables changed in Sensitivity analysis

Individual energy and material balances could not be obtained for the natural gas production and distribution steps (extraction, pipeline transport). Therefore a sensitivity analysis which varied the wellhead gas composition could not perform. Because of large volume, the sensitivity results tables have not attached to this paper. They can submit by author.

2.9 Impact Assessment

Life cycle impact assessment is a means of examining and interpreting the inventory data from an environmental perspective. There are several; options for analyzing the systems impact on the environment and human. To meet the needs of this study, categorization and less-is-better approaches have been taken. See SETAC (1997, 1998) for additional details about the different methods available for conducting impact assessments. Table 8 summarizes the stressor categories and stressors from the natural gas treatment system. A discussion of these stressor categories as well as information about the known effects of these stressors is studied by site HSE group.

Stressor categories		Stressors	Major impact category H = human health E = ecological health	Area impacted L = local (county) R = regional (state) G = global
Major	Minor			
Ozone depletion compounds		NO	H,E	R,G
Climate change	Greenhouse gases	CO_2, CH_4, N_2O, CO and NO_x (indirectly), water vapor	H,E	R,G
	Particulates		H,E	L,R
Contributors to smog	Photochemical	NO_x, VOCs	H,E	L,R
Acidification precursors		SO_2, NO_x, CO_2	H,E	L,R
Contributors to corrosion		SO_2, H_2S, H_2O	E	L
Other stressors with toxic effects		NMHCs , benzene	H,E	L
Resource depletion		Fossil fuels, water, minerals, and ores	E	R,G
Solid waste		Catalysts, coal ash (indirectly), flue gas clean up waste (indirectly)	H,E	L,R

Table 8: Impacts Associated with Stressor Categories

2.10 Improvement Opportunities

The component of life cycle assessment known as improvement is used to identify opportunities for gas plant energy efficiency has the largest effect on the system stressors (resource, emissions, waste, and energy use) and thus this variable has the largest environmental impact. Because gas treatment plant and are conventional technologies where improvements have been made in the past, significant increases in yields through changes in furnace/turbines designs or chemical types are not expected. However, it is important to note that the gas treatment plant should be operated as efficiently as possible to minimize the environmental burden of the system.

Reducing the natural gas losses is an opportunity for improvement and this would improve GWP of the system. The base case analysis shows that 11% of the GWP is a result of methane emissions and 76wt% of the total system methane comes from natural gas lost during production and distribution. If the losses were reduced from 1.4% to 0.5% methane would account for 6% of the GWP instead of 11%. Reducing the natural gas losses would also improve the energy balance of the system. Depending on the composition of the natural gas, approximately 48,400 J of energy are lost per gram of natural gas that leaks to the atmosphere (LHV basis). For the base case, 2.7 MJ are lost per kg of gas produced and this would be reduced to 0.5 MJ/kg of gas if the natural gas losses were only 0.5%. As discussed before, the new programs in Sarkhoon gas treatment plant are defined to reduce methane emissions from natural gas treatment which includes:

- Reduction of excess fuel gas
- Eco-mapping
- Energy Audit
- Gas turbine fuel system modifications
- Solar Dew waste water purification
- Co_2 recovery from flue gases
- Smart emissions monitoring and control

3. REFERENCES:

1- EIA, Iran Country Analysis Briefs, Jan 2006
2- NIGC, Annual Report, 20 march 2003- 19 march 2004
3-Harrison, M.R.; Shires, T.M.; Weasels , J.k., Cowgill , R.M. (1997). "Methane Emissions from the Natural Gas Industry." Project Summary. United States Environmental Protection Agency. Report # 600/SR-96/080. National Risk Management Research Laboratory. Research Triangle Park, NC.
4-Houghton, J.T.; Meira Filho, L.G.; Callander, B.A.; Harris, N.;Kattenberg, A.;Maskell, K., eds. (1996*). Climate Change 1995. The Science of Climate Chang.* Published for the Intergovernmental Panel on Climate Change. New York: Cambridge University Press.
5-Kirchgessner, D.A.; Lott, R.A.; Cowgill, R.M.; Harrison, M.R.; Shires, T.M. (1997) "Estimate of Methane Emissions from the U.S. Natural Gas Industry." *Chemosphere.* Vol .35, No. 6;pp. 1365-1390
6-Kirk-Othmers Encyclopedia of Chemical Technology . (1993) 4 th Edition, Vol. 12,pp. 324-335.
7-Lacson, J.G. (1999). *CEH Product Review: Natural Gas.* Chemical Economics Handbook. SRI International . Menlo Park ,CA.Volume 4. Section 266.2000.

4. LIST of TABLES:

Table 1: Material and Energy Balance in Natural Gas Plant
Table 2: Natural Gas Plant Data
Table 3: Natural Gas composition in Feedstock and Sale Gas of Plant
Table 4: Average Air Emission
Table 5: Greenhouse Gases Emissions and Global Warming Potential
Table 6: Average Energy Requirements (LHV basis)
Table 7: Variables changed in Sensitivity analysis
Table 8: Impacts Associated with Stressor Categories

5. LIST of FIGUERS:

FIG 1: Sarkhoon block flow diagram of the natural gas plant
FIG 2: System Boundaries for Natural Gas Treating Plant